Spring 5-2002

# Concrete Canoe 2002

Samuel Lynn Harrison
*University of Tennessee - Knoxville*

**UNIVERSITY HONORS PROGRAM**

**SENIOR PROJECT - APPROVAL**

Name: Samuel L. Harrison

College: Engineering Department: Civil

Faculty Mentor: Dr. Eric Drumm

PROJECT TITLE: Concrete Canoe 2002

I have reviewed this completed senior honors thesis with this student and certify that it is a project commensurate with honors level undergraduate research in this field.

Signed: Eric C. Drumm, Faculty Mentor

Date: 5-6-02

Comments (Optional):

# UNIVERSITY HONORS PROGRAM

## SENIOR PROJECT - PROSPECTUS

Name: Sam Harrison

College: Engineering Department: Civil

Faculty Mentor: Dr. Eric Drumm

PROJECT TITLE: Concrete Canoe 2002: Design, Construction, and Presentation of ASCE's concrete canoe Design 2002

PROJECT DESCRIPTION (Attach not more than one additional page, if necessary):

My project will involve leading the concrete canoe design team for 2001-2002. This will involve leading the team, making marketing contacts, building the canoe and finally presenting the canoe at conference. I will write the paper for the canoe as my paper for the Honors Program

Projected completion date: April 5, 2002

Signed: [signature]

I have discussed this research proposal with this student and agree to serve in an advisory role, as faculty mentor, and to certify the acceptability of the completed project.

Signed: Eric C. Drumm, Faculty Mentor

Date: 11-12-01

**Return this completed form to The University Honors Program, F101 Melrose Hall, following your first presentation in the Senior Project Seminar.**

# The University of Tennessee


# 2002 Southeastern Conference
# Tallahassee, Florida
# Concrete Canoe Competition

## Table of Contents



Written by: Samuel Lynn Harrison
Edited by: Katherine R. Mitchell

The 2002 University of Tennessee Concrete Canoe Team is in compliance with this year's National Concrete Competition Rules including the following statements:

1. The construction of the canoe has been performed in complete compliance with the rules and regulations of the National Competition.

2. The ten (10) registered participants intended to be registered at the National Competition are qualified student members and National Student Members of ASCE as specified in the rules and regulations of the National Competition.

3. The canoe has been completely built within the current academic year of the competition.

Sam Harrison, Team Captain

## 1.0 Executive Summary

On a cool day in Auburn, Alabama, a group of spectators watched the goliath *Orange Crush* lumber through the water at a pace rivaling that of driftwood. The concrete canoe was over 4cm (1.57in) thick and weighed 102kg (225lb), and the boat finished last of those to cross the finish line. While this was an improvement over the previous year's canoe christened *Broke Coming Out of Mold,* the 2002 Concrete Canoe Team expects far better results from this year's canoe.

In the fall of 2001, with the memories of the resounding failure fresh in our minds, the 2002 concrete canoe team began work. Our first goal was to raise enough money to fund the canoe project without need for financial support from the Department of Civil and Environmental Engineering. Our efforts during the fall semester were dedicated to gathering enough materials and money to build a competitive canoe. In early January, the first samples of concrete were mixed and tested, yielding one clear choice for the mix. Once a mix was chosen, reinforcement options were explored. Kevlar® and a carbon fiber mesh were the two reinforcements considered. From plate bending and workability tests the carbon fiber clearly out-performed the Kevlar®. Further testing determined 3 layers of carbon fiber sandwiched between layers of concrete provided the best strength. Once the materials were selected, construction preparation commenced. A Styrofoam male mold was covered with a grid of toothpicks set to the correct concrete depth at equal lengths of the boat. The process was derived from "blue topping" or setting grade in highway construction. The final product has a mass of about 45g (100lbs), a length of 5.79m (19.0'), a width of 0.76m (2.5'), and a wall thickness of 9.53mm (0.38"). The color scheme represents the connection between American Society and engineering. This boat is a leap in canoe technology for the University of Tennessee hence we christened the canoe *Quantum.*

## 2.0 Introduction

"The University of Tennessee began as Blount College, chartered on September 10, 1794, by an act of the legislature of the Southwest Territory meeting in the territorial capital, Knoxville. The college was small at its inception; it struggled for the next thirteen years with a small student body and an even smaller faculty. In 1807, the institution received a new designation-East Tennessee College--and in 1840 was elevated in stature as East Tennessee University. Following the Civil War, the State of Tennessee made the University the beneficiary of the Morrill Act of 1862, which allocated federal land or its monetary value to the various states for the teaching of "agricultural and mechanical" subjects and to provide military training to students. Thus, the University of Tennessee (its designation after 1879) became a land-grant institution." (Klein, 2002)

From humble beginnings the University of Tennessee now has more than 26,000 students and 400 academic programs. As well as having a wide range of academic activities, we also play a little football on Saturdays.

Over the past few years the concrete canoe teams have been less successful than the football team was this year in Gainesville. In an attempt to turn around the misfortune of concrete canoe teams in the past, our team went through an intensive search for what other schools were doing to be competitive. We looked at the University of Alabama Huntsville (UAH), Florida Institute of Technology, Southern Polytechnic State University, Oklahoma State University, Michigan

State University and the University of Central Florida. We gleaned information from others and applied this knowledge to the 2002 design. The result is a canoe around 56kg (123lbs) lighter than last year's canoe and a much better understanding of what is required to build a quality canoe. The main goal of this year's team was to produce a competitive canoe that was easy to construct.

## 3.0 Hull Design

The concrete canoe competition requires good straight-line speed and tracking for the sprint races, which dictates a long and slender boat with a deep keel. However, the slalom races require good maneuverability and turning, which requires a short wide boat with a flat bottom. In an attempt to balance these two contradicting needs, our hydraulic team has come up with a shallow keel on a flat-bottomed boat with a wide center section. While this design does not allow for the greatest speed or the greatest maneuverability, it does give the paddlers a boat that will respond to their stroke input. The finished length is 5.79m (17.0') with a width of 0.76m (2.5ft). The hull is symmetrical, which will balance the paddlers and allow for easy turning around the buoys for the slalom race. The hull design is not a copy of any existing canoe, however, the design selected fits what a "traditional" canoe would look like and is limited in length to the trailer used to transport the canoe.

## 4.0 Structural Design

Fitting with the overall strategy for the 2002 concrete canoe, the target goals for the structural design were straightforward constructability and workability. Therefore, instead of designing a concrete mix for strength, we designed our mix for workability. We were aiming for the consistency of drywall mud that would "stick" to a vertical surface. This was important when the canoe was poured because if the mix had too high of a slump, it would simply have slid down the side of the mold. General parameters were set for the canoe mix. Five different mixes were tested and the mix designs for each can be seen below in Table 1.

Table 1: Mix Design

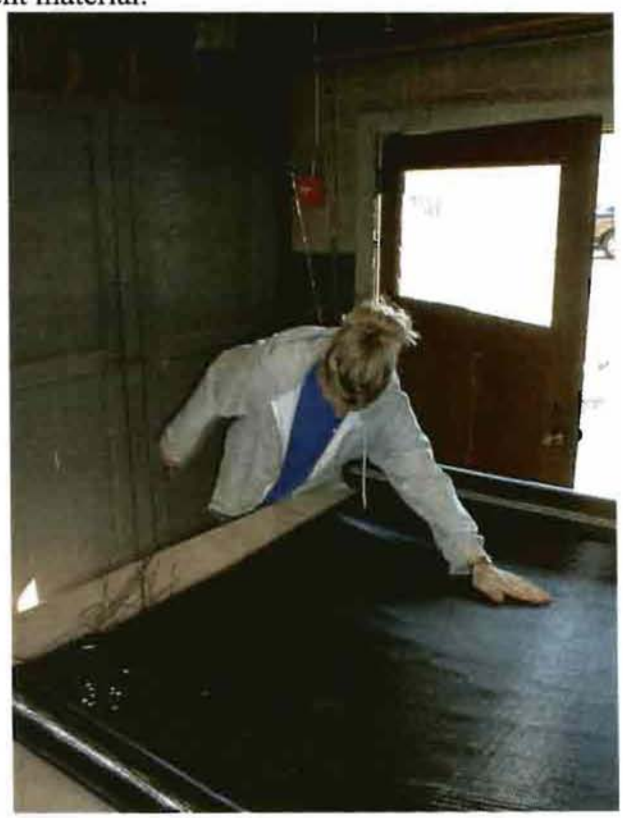
| | Binder | | Aggregate | | Other | | | | | | Properties | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Portland Cement | | Recyclospheres | | Latex | | Acrylic | | Water | | Unit Weight | | Buoyant | Workability | 7 Day Strength | |
| | kg/m³ | lb/yd³ | kg/m³ | lb/yd³ | kg/m³ | lb/yd³ | kg/m³ | lb/yd³ | kg/m³ | lb/yd³ | kg/m³ | lb/yd³ | | | Mpa | psi |
| Mix A | 582 | 982 | 489 | 825 | 0 | 0 | 0 | 0 | 575 | 970 | 1648 | 2777 | Yes | Good | 2.03 | 297 |
| Mix B | 345 | 582 | 590 | 994 | 158 | 267 | 0 | 0 | 460 | 776 | 1554 | 2619 | Yes | Good | 0.39 | 57 |
| Mix C | 386 | 650 | 331 | 558 | 76 | 129 | 39 | 66 | 230 | 388 | 1062 | 1790 | Yes | Excellent | 2.20 | 325 |
| Mix D | 636 | 1072 | 380 | 640 | 127 | 213 | 0 | 0 | 345 | 582 | 1488 | 2508 | No | Good | 3.2 | 467 |
| Mix E | 498 | 839 | 573 | 965 | 350 | 589 | 39 | 66 | 223 | 376 | 1682 | 2835 | Yes | Fair | 1.74 | 255 |

Use of the acrylic fortifier increases the stiffness of the concrete and increases water resistance. The latex increases tensile strength and flexural strength as well as durability. In addition, the latex fills microcracks and decreases permeability.

These samples were poured into 7.6cm (3.0") by 15.2cm (6.0") cylinders and broken in compression. It was assumed that the tensile strength of each was linearly related to the compressive strength. In addition to strength testing, a cube of each sample was soaked in water for one week. From this test, mix D was immediately eliminated because it was not buoyant. From the water tank test and compressive strength test, mix C and mix E were selected as final candidates. Each mix was placed over a Kevlar® mesh and a carbon fiber mesh. In the placing of the mixes over the reinforcement, mix C proved to be the most workable. Mix E would not go between the mesh well and a thin sheet of mix E could not be produced. From this test mix C was the clear-cut choice.

## 5.0 Reinforcement

When exploring reinforcement materials, the target material should be easy to work with, have a high modulus of elasticity, bond well to concrete, and have high tensile strength. The first material explored was Kevlar®. This made sense because the canoe team had an entire roll left over from a previously failed concrete canoe. After some tests with the Kevlar®, it was clear why the previous canoe had failed. The Kevlar® did not bond well to the concrete and was difficult to cut and place. The second material we explored was a carbon fiber weave. As soon as we started working with the carbon fiber it was clear this was going to be our reinforcing material. The strength and workability of the material as well as the very short development length made carbon fiber the choice for reinforcement material.



Top: Steven and Brad working
Right: Christina pulling fibers

To test for composite action, two plates were made with three layers of carbon fiber, with two layers at the extreme edges of the plate and one in the center. The plates were placed in water to soak for 24 hours and then loaded in a cantilever mode. The concrete proved far more flexible than we expected. The behavior of similar materials has been described "as the section is bent to the point where the stiffness of the outermost compressive layer begins to decrease, the movement of the centroid forces the middle layer into compression. Assuming that the fibers in this layer are completely constrained, the mesh is as stiff (in compression) as it is in tension. In this case the centroid remains close to the middle of the plate keeping the moment of inertia high and the stresses low." (Coign, 2000)

With this concept in mind, we pushed ahead with further plate testing and settled on a cross section with three layers of carbon fiber and a total thickness of 12.7mm (0.5"). To allow the concrete to pass through the mesh as well as meet the sand permeability test, every other strand was pulled out of the weave leaving half of the original strands in place. The carbon fiber fabric is a non-impregnated mesh with 3000 fibers per tow spaced at 3.18 mm (0.125") intervals. Each tow is 0.19mm (0.0075") thick by 1.07mm (0.042") wide. The tensile strength of the carbon mesh is 3.65GPa (530ksi) with a modulus of elasticity of 231GPa (33.5Mpsi).

As suggested by Cogin (2000), "the required strength for four paddlers is statically equivalent to a 31.2Nm (23lb-in) moment applied to a 2.54cm (1.0") wide plate."

## 6.0 Construction

From the beginning of our canoe design our goal has been ease of construction. The mix design and reinforcement were all selected to make construction of the canoe less complicated. To simplify construction, a Styrofoam male mold was covered in a tight wrap of plastic to act as the releasing agent. This posed many problems as some of the wrinkles in the plastic were bigger than the thickness of the hull. Through a painstaking process the wrinkles were cut out, and the plastic was wrapped tighter and tighter against the mold.

To set the depth of concrete, toothpicks were laid out in a grid pattern over the surface of the boat. The correct depth of concrete, location of carbon fiber, and where to stop concrete were all marked by colors on the toothpicks. With over 152 toothpicks in the Styrofoam mold it was affectionately called "Hellraiser."

All of the concrete mixing was done by hand in large buckets for fear that a mechanical mixer would crush some of the aggregate. All of the concrete was placed on the canoe by hand with dry wall and masonry tools. The concrete was set at the correct depth at all of the toothpicks, and then sections of reinforcement were cut and placed on top of the wet concrete. Dry wall knives were used to sink the fibers into the concrete to insure a good bond. This process was repeated for each of the remaining layers of concrete.

After smoothing the final layer of concrete, a moist room was set up around the canoe table. A wooden frame was suspended from the ceiling, and sheets of plastic were stapled onto the frame to create an enclosure. Two humidifiers were placed in the tent, which was kept at around 65% humidity. After 24 hours the tent was removed, and the boat was allowed to cure for an additional 72 hours with a humidity of 30-40%.

Top: Ronny smoothing concrete
Right: Mike inspecting the moist room

Seven days after the pour, the canoe was sanded by hand in a soft light to expose high spots. The inside of the canoe was much rougher than the outside. Apparently the latex or the acrylic fortifier caused the plastic sheet to deform which put a ripple pattern on the inside of the canoe. Some of the places were patched, some were sanded, and others were left for an unintentional yet artistic effect.

## 7.0 Project Management

While different from most concrete canoe teams, our team employed a strong leader/follower system where decisions were made by relatively few individuals and the rest of the team was responsible for "making it happen." While this hierarchical model does not set well with today's business philosophy of team involvement and everyone being equal, it worked very well for our team. This management style had an additional benefit of being a cost saving device since the majority of the team was classified as laborers in the cost analysis.

We divided the team into four groups, each with a specific task. The mix design group was responsible for developing a lightweight water resistant mix with good workability. The hydraulic group was responsible for the design of the boat, and the construction group was responsible for determining the best methods for construction. The last group was the racing team. This group included the paddlers and trainers to get the paddlers ready for competition. All of these groups reported directly to the project manager. To keep everything on track and everybody informed meetings were scheduled every week for progress reports from each group.

## 8.0 Cost Assessment

The original estimate for the concrete canoe was \$100,000 with labor cost comprising the bulk of the cost. As seen in Appendix 1, our total costs were a mere \$68,869. This is far below the estimate. The labor costs were \$66,039 with a material cost of \$2,830.

## 9.0 Competition Results

As we expected we had a very competitive boat. Overall we placed 7th of 19 canoes and finished 5th and 6th in many of the races. The final product, races, and canoe paper all received points towards the overall placement. I am very proud of our paddlers and our canoe team. They did an excellent job building and racing our canoe. Below is a table that summarizes the placements in each component of the competition.

| Table 2: Results | |
|---|---|
| Oral Presentation | 14th |
| Display | 17th |
| Paper | 9th |
| Final Product | 7th |
| **Races Overall** | **6th** |
| Women's Endurance | 14th |
| Women's Sprint | 8th |
| Men's Endurance | 5th |
| Men's Sprint | 5th |
| Combined | 6th |

Katherine and Kelly coming in from a race

On the Women's Sprint we were rammed by Puerto Rico and they finished ahead of us by 1 second. Apparently the judges did not feel this was a problem although our girls had to stop paddling because Puerto Rico was in our lane. On the Women's Endurance, were penalized an additional 6 minutes for failing to pass the slalom buoys on the correct side. Our women decided they would accept the penalties and miss the buoys on the right. The judges felt this was against the "spirit of competition" and gave us the penalty for missing 6 buoys although we only missed 4. Overall, I feel the judging was biased towards schools that traditionally do well and some of the other schools violations were overlooked by a majority of the judges. In the end, the judging did not matter as we have ½ of the points of the school in 6th place. In addition, for each part of the competition, points are received for placing in the top 10, therefore there is no difference between placing 11th and 20th in any given event.

Kevin and Patrick before a race

## 10.0 Recommendations for Next Year

For future competitions, we need to focus on the display, oral presentation, and paper as much as the canoe. We had lost the overall competition as soon as our paper was received. The canoe needs to be poured and curing over winter break thus allowing all of the spring to work on the display and oral presentation. The judges love a themed canoe. Pick a theme and run it through the display, oral presentation and the paper. The competitive boats look like fiberglass. They achieve this by sanding and patching dozens of times. To get a smooth boat we must do the same. We need to find an effective way to construct the boat. The toothpick holes were a bad idea. They caused a leak the day of the competition and a created a crack in the bottom of the boat. While this turned out not to be more than a superficial crack, it caused me a lot of heartburn the day of the races.


Canoe at final product display

## 11.0 Summary

Our 2002 concrete canoe team had the goal of making a competitive boat as easily as possible. This philosophy started with the mix design. We did not design the mix for strength. We designed for workability, and strength was one of the variables. The hydraulic design is that of a standard canoe with nothing very radical. As expected, the canoe was not extremely fast, however, we do know it worked. Overall, the team is very satisfied with the results of this year's project, and we hope to serve as a stepping-stone for next year's team.


Patrick and Kevin paddling

## Appendix 1: Technical Data Sheets

### *RECYCLOSPHERES*$_{TM}$

Ceramic Hollow Microspheres

**TYPICAL PRODUCT SPECIFICATIONS**

| GRADES | SG-300 | LF-300 | MG-150 |
|---|---|---|---|
| *Physical Properties* | | | |
| Specific Gravity (@ 22 °C) | 0.6 - 0.8 | 0.6 - 0.8 | 0.6 - 0.8 |
| Bulk Density (lbs. $ft^3$) | 20 - 25 | 20 - 25 | 20 - 25 |
| pH In Water | 6.5 - 7.5 | 6.5 - 7.5 | 6.5 - 7.5 |
| Softening Point | > 2700°F | > 2700°F | > 2700°F |
| Size Range (Microns) | 10 - 300 | 125 - 300 | 10 - 150 |
| Max % Particles Below | 95% - 100% | 95% - 100% | 95% - 100% |
| Crush Strength (psi) | 3,500 - 5,000 | 3,500 - 5,000 | 3,500 - 5,000 |
| Average Wall Thickness | 10% Diameter | 10% Diameter | 10% Diameter |
| *Chemical Properties* | | | |
| SHELL | | | |
| Silica ($SiO_2$) | 55% - 65% | | |
| Alumina ($Al_2O_3$) | 25% - 35% | | |
| Iron Oxide ($Fe_2O_3$) | < 5% | | |
| GAS | | | |
| Carbon Dioxide | 65% - 75% | | |
| Nitrogen | 25% - 35% | | |

Latex Provided by Dow Chemical Corp.

| | |
|---|---|
| Styrene/butadiene polymer | 40-60% |
| Water | 40-59% |
| Proprietary stabilizer | 1-5% |

Acrylic Fortifier provided by Bonsal

Features and Benefits as provided by Bonsal

- Increases Bond Strength
- Improves Abrasion and Water Resistance
- Will not Discolor White Products
- Improves Freeze-Thaw Resistance
- Improves Flexibility and Elongation After Exposure and Aging
- Improves Workability
- Improves Corrosion Resistance
- Interior or Exterior
- Superior Wet Strength

| | **Carbon Fiber** | | **ITEM #FC033-162PD-0102AQ** |
|---|---|---|---|
| DESCRIPTION: | FABRIC Carbon 162g/4.8oz@102cm/40" Plain 12x8pics 3kx3k AMOCO T300 | | |
| PACKAGING: | Fabric tightly wound onto 3" i.d. cardboard tubes; wrapped in clear plastic; packaged into double-walled 250/psi test cardboard boxes; roll is suspended in center of box by end-plates on both ends of tube; roll held tight in box by cardboard shims filling free end-play. | | |
| SPEC TYPE | SPEC DESCRIPTIONS | | DEFINITIONS |
| "FABRIC" | FABRIC "U.S." SPECS: | FABRIC "METRIC" SPECS: | FABRIC DEFINITIONS: |
| Areal Weight | Oz/sq/yd = 4.8 oz. | gram/sq/m. = 162 gr. | The weight of the fabric per square meter or square yard. |
| Fabric Width | inches = 40" | cm = 102 cm. | The width of the fabric in US inches; width in centimeters. |
| Thickness; Dry/Laminate | inch = 0.009"/ 0.0076" | mm =0.228 mm / 0.171mm | Thickness in inches or millimeters. |
| Roll Length | yards(+/-)=100yd.(+/-2) | meters(+/-)=91 m.(+/-1.5) | Roll linear length, plus+ or minus tolerance. |
| "WEAVE" | WEAVE DETAIL SPECS: | | WEAVE DEFINITIONS: |
| Style / Pattern | "Plain" Weave | | Weave style or pattern of woven fabric or material. |
| WARP "Ends" | Count/inch=12 ends/in. | Count/meter=472 ends/m. | Lengthwise direction fiber count. |
| FILL "Picks" | Count/inch=8 pics/in. | Count/meter=315 pics/in. | Width / Across direction fiber count. |
| Edge Style | Type = Leno | Stitch detail = 2x Double Leno fibers | Lengthwise stitching style o fabric edge. |
| Edge Fiber | Type = Kevlar | Denier = 195 d. | Type of fiber used in lengthwise stitching. |
| Fringe Edge Trim | inch = 0.5" | cm = 1.27 cm. | Length of the fibers outside of the usable fabric area. |
| Tracers "TYPE" | Material = NONE | Count/in/m. NA | Fibers of different type & pattern inserted into weave. |

## Appendix 2: Design Calculations

### Table II.C.I - Summary of Mixture Proportions

**Mixture Designation: Mix C**

| Air and Cementitious Materials | | | |
|---|---|---|---|
| Component | Quantity (whether base or batch) | | Units |
| air content by volume of concrete | Standard Test N/A | *AIR:* | % |
| cement (plain), | ASTM Type: Type I | 396 | kg/m$^3$ |
| other cementitious material 1* | Description: N/A | $m_1$: | kg/m$^3$ |
| other cementitious material 2* | Description: N/A | $m_2$: | kg/m$^3$ |
| other cementitious material 3* | Description: N/A | $m_3$: | kg/m$^3$ |
| other cementitious material 4* | Description: N/A | $m_4$: | kg/m$^3$ |
| mass of all cementitious materials | 396 | | kg/m$^3$ |
| cement to cementitous materials ratio | 1 | | kg/m$^3$ |
| **Aggregates** | | | |
| | Base Quantity (SSD aggregates) | Batch Quantity (Aggregates at stock moisture content) | |
| mass of agg. from Recyclospheres$_{TM}$ | 300 | 300 | kg/m$^3$ |
| mass of agg. from source 2 | $W_{SSD,2}$: | $W_{stk,2}$: | kg/m$^3$ |
| mass of agg. from source 3 | $W_{SSD,3}$: | $W_{stk,3}$: | kg/m$^3$ |
| mass of agg. from source 4 | $W_{SSD,4}$: | $W_{stk,4}$: | kg/m$^3$ |
| weight of combined aggregate | 300 | 300 | kg/m$^3$ |
| **Water** | | | |
| water | *W:* | 234 | kg/m$^3$ |
| vol. of latex | 77692 | | kg/m$^3$ |
| vol. of acrylic | 39788 | | kg/m$^3$ |
| vol. of admixture #3 | $x_3$: | | kg/m$^3$ |
| vol. of admixture #4 | $x_4$: | | kg/m$^3$ |
| water from latex | | 40 | kg/m$^3$ |
| water from acrylic | | 30 | kg/m$^3$ |
| water from admixture #3 | | $w_{admx,3}$: | kg/m$^3$ |
| water from admixture #4 | | $w_{admx,4}$: | kg/m$^3$ |
| total free (surplus) water from all aggregates | | 0 | kg/m$^3$ |
| total water | 304 | 304 | kg/m$^3$ |
| concrete density | 1000 | 1000 | kg/m$^3$ |
| water to cement ratio | 0.77 | | |
| water to cementitious material | 0.77 | | |

Reinforcement measured 1.5mm (0.17") thick. The canoe section is 9.53mm (0.375") thick, therefore with 3 layers of reinforcement they comprise 47% of the total thickness.

The total paint thickness is 1.58mm (0.063").

The removable seats have a length of 30.48cm (12.0") and a width of 20.32cm (8.0"

## Appendix 3: Cost Assessment

| Direct Labor | | | |
|---|---|---|---|
| Title | Raw Labor Rates ($/hr) | Hours (hr) | Cost ($) |
| Principal Engineer | 40 | 75 | 3000.00 |
| Project Manager | 30 | 50 | 1500.00 |
| Product Engineer (PE) | 25 | 45 | 1125.00 |
| Graduate Engineer (EI) | 18 | 20 | 360.00 |
| Technician/Draft Person | 14 | 45 | 630.00 |
| Word Processing | 12 | 15 | 180.00 |
| Foreman of Construction | 35 | 50 | 1750.00 |
| Laborer | 25 | 525 | 13125.00 |
| | | Total Cost | $ 21,670.00 |

With the adjustment factors for direct and indirect employee cost,
The total labor cost comes to $66,039.00

| Materials | Unit Cost ($) | Unit Measure | Amount Used | Material Cost |
|---|---|---|---|---|
| **Research and Development** | | | | |
| Mold Construction | | | | |
| Styrofoam | 275 | LS | 1 | 275 |
| Outside Construction | 200 | $/hr | 1 | 200 |
| Great Stuff | 6.25 | $/can | 1 | 6.25 |
| Plastic Sheet | 25 | $/roll | 0.5 | 12.5 |
| **Construction of Final Product** | | | | |
| Concrete Canoe | | | | |
| Cement | 0.085 | $/kg | 26.52 | 2 |
| Acrylic Fortifier | 2.32 | $/liter | 2.67 | 6 |
| Latex Admixture | 5.81 | $/liter | 5.21 | 30 |
| Glass Bead | 0.12 | $/kg | 22.73 | 3 |
| Carbon Fiber | 68 | $/m$^2$ | 15.83 | 1076 |
| Paint-Primer | 17.17 | $/liter | 12 | 206 |
| Paint-Clear Coat | 65.96 | $/liter | 2 | 132 |
| Paint-Orange | 65.96 | $/liter | 8 | 528 |
| Construction Supplies | | | | |
| Sandpaper | 0.25 | $/sheet | 50 | 13 |
| Gloves | 2.5 | $/pair | 6 | 15 |
| Mask | 2 | $/box | 1 | 2 |
| Knives | 1.69 | $/unit | 10 | 17 |
| Mixer | 6.81 | $/unit | 1 | 7 |
| Humidifiers | 20.98 | $/unit | 2 | 42 |
| | | Total Material Cost | | 2572 |

With the 10% markup added to the material costs, the materials were $2830.0Which makes a total cost of the project **$68,8669.02**

## Appendix 4: References

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SSR Smith Seckman Reid, Inc.

sds
SMART DATA STRATEGIES

SPHERE SERVICES INC.
The Cenosphere Company

PROFESSIONAL ENGINEERS
INCORPORATED 1999
PE
PROFESSIONAL ENGINEERS, INC.

FLINTCO
Constructive Solutions

ICT
I.C. Thomasson Associates, Inc.